Beyond the 3SM generation at the LHC era
Workshop
04 Sept. 2008
CERN

Fourth SM Family and Higgs at Hadron Colliders

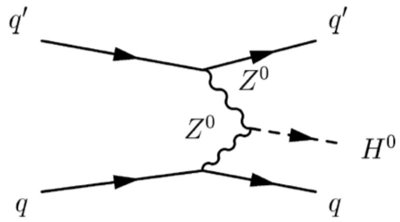
Engin Arık [1]
Orhan Çakır [2]
Serkant Ali Çetin [3]
Saleh Sultansoy [4,5]

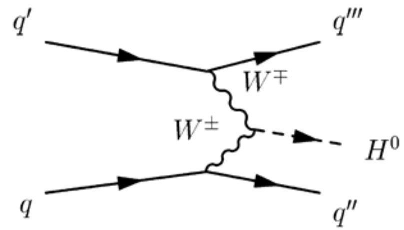
[1] Boğaziçi University, İstanbul
[2] Ankara University
[3] Doğuş University, İstanbul
[4] TOBB ETU, Ankara
[5] Institute of Physics, Baku

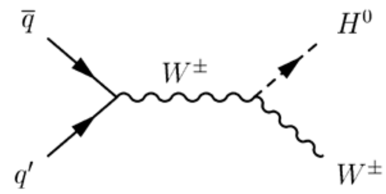
$pp \rightarrow ggX \rightarrow hX$

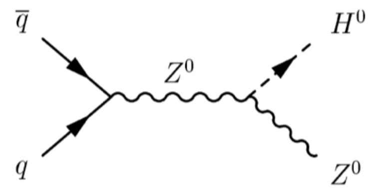
Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

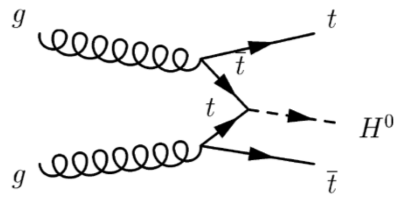
Higgs production at hadron colliders



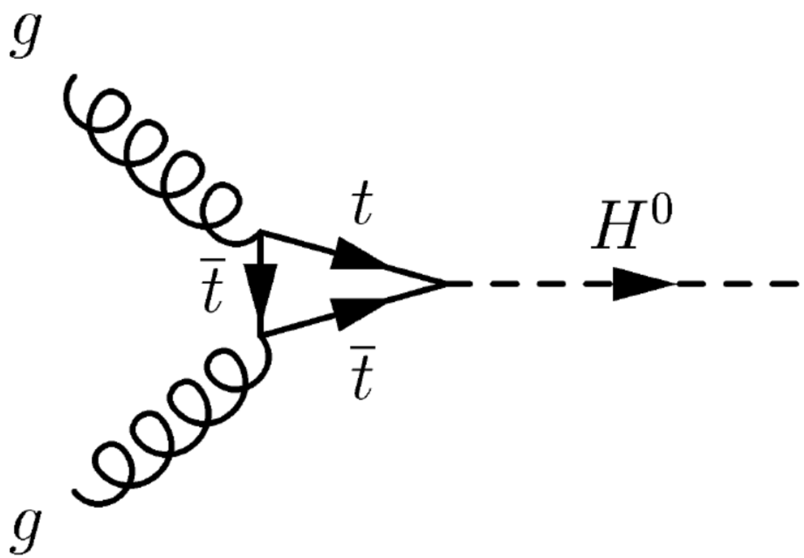








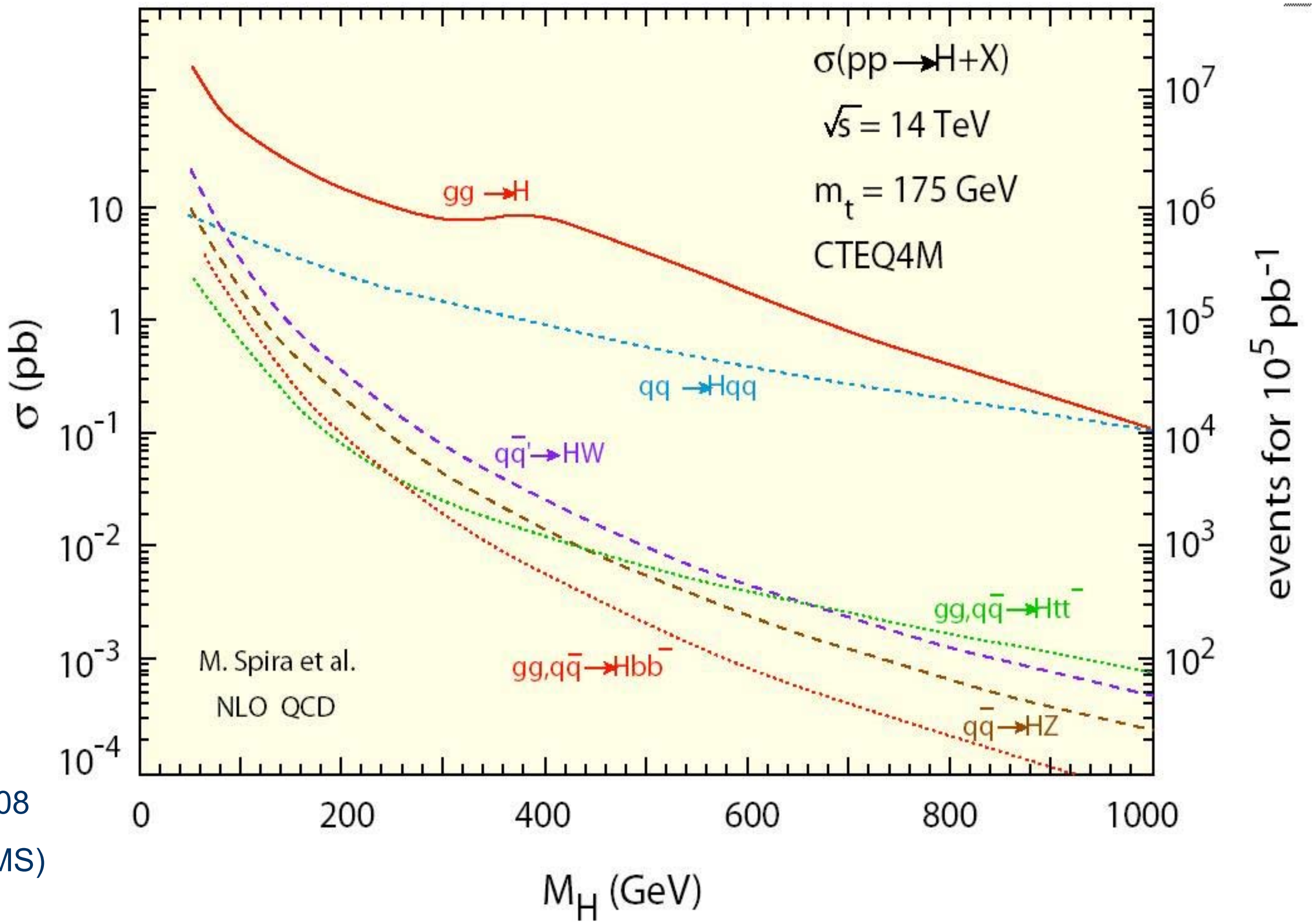
Higgs Boson production at hadron colliders is <u>dominated</u> by **gluon-gluon fusion** process, hence any change in the cross-section of the gluon-gluon fusion will practically result with the same amount of change on the total production cross-section of the Higgs.



$$pp \rightarrow ggX \rightarrow hX$$

Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

Higgs production at LHC



Ricardo Gonçalo @ ICHEP08
(on behalf of ATLAS and CMS)

$pp \rightarrow ggX \rightarrow hX$

Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

Enhancement of Higgs production cross section

ATL-PHYS-98-125 / ATLAS physics note

$$\sigma(p\bar{p} \rightarrow hX) = \sigma_0 \tau_h \int_{\tau_h}^{1} \frac{dx}{x} g(x,Q^2) g(\tau_h/x, Q^2)$$

$$\sigma_0(gg \rightarrow h) = \frac{G_F\, \alpha_s^2(\mu^2)}{288\sqrt{2}\,\pi} |I|^2$$

$$I = \Sigma I_q$$

$$\lambda_q = \left(\frac{m_q}{m_H}\right)^2$$

$$I_q = 3[2\lambda_q + \lambda_q(4\lambda_q - 1) f(\lambda_q)]$$

in 3 SM family case; $q = t, b$
in 4 SM family case; $q = t, b, u_4, d_4$

hence enhancement is given by the ratio of
$(I_b + I_t + I_{u4} + I_{d4})$ to $(I_b + I_t)$

$$f(\lambda_q) = \frac{1}{2}\left(ln\frac{\eta^+}{\eta^-}\right)^2 - \frac{\pi^2}{2} - i\pi ln\frac{\eta^+}{\eta^-} \;, \qquad for \;\; \lambda_q < \frac{1}{4}$$

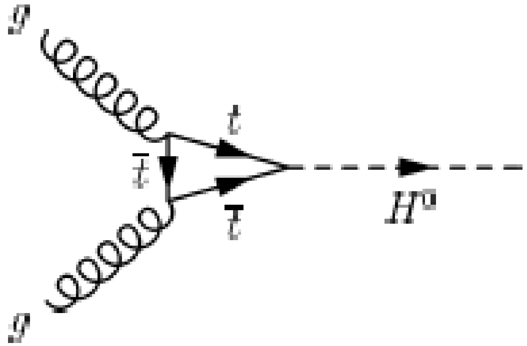
$$f(\lambda_q) = -2\left(arcsin\frac{1}{2\sqrt{\lambda_q}}\right)^2, \qquad for \;\; \lambda_q > \frac{1}{4}$$

$pp \rightarrow ggX \rightarrow hX$

Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

Enhancement of Higgs production cross section

Existence of the extra SM generations leads to an essential increase of the Higgs boson production cross section via gluon gluon fusion at hadron colliders

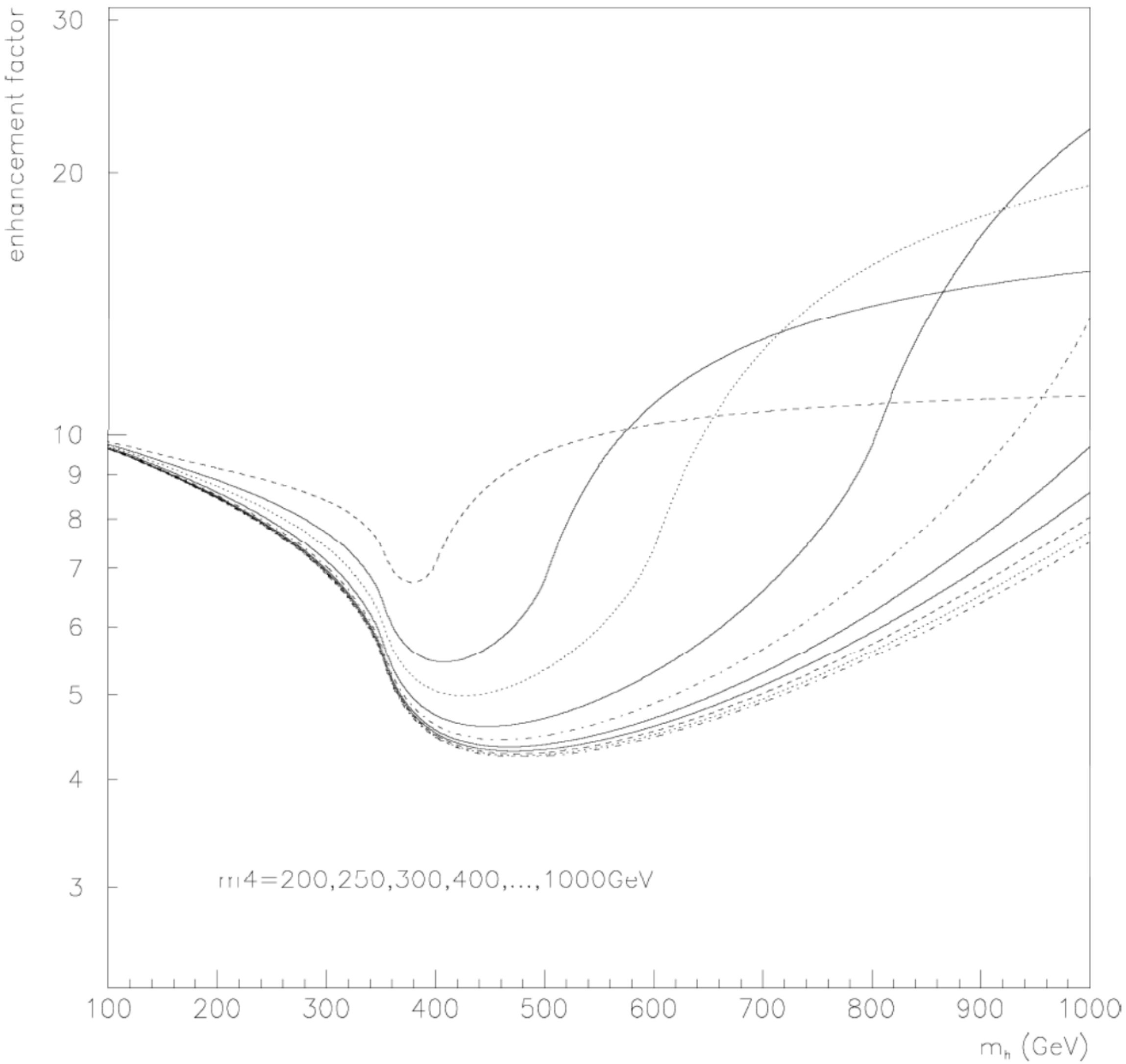


$+ (t \rightarrow b) + \mathbf{(t \rightarrow u_4) + (t \rightarrow d_4)}$

Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

Enhancement of Higgs production cross section

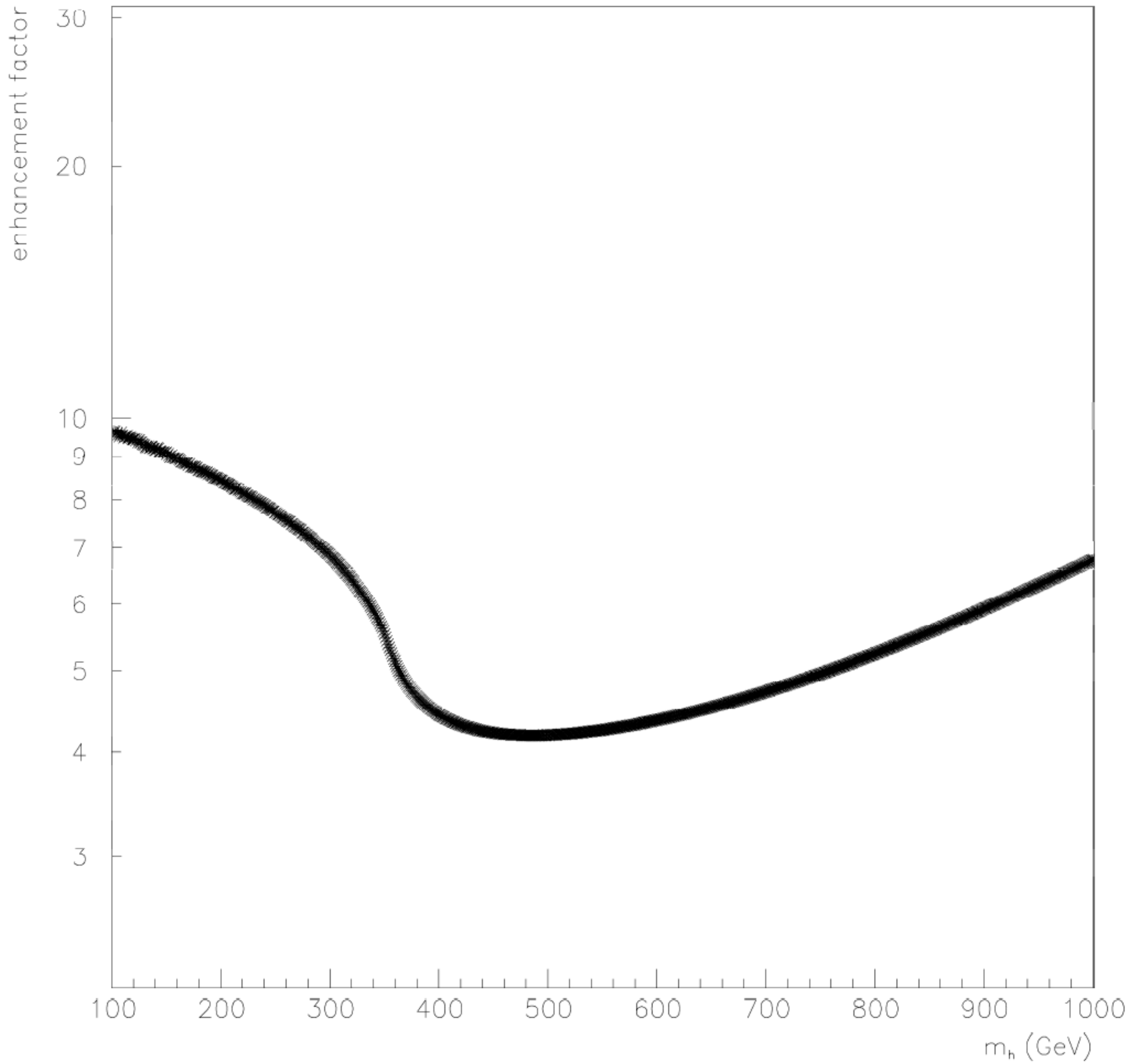
- enhancement factor as a function of the Higgs boson mass for various 4th family quark masses



Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

Enhancement of Higgs production cross section

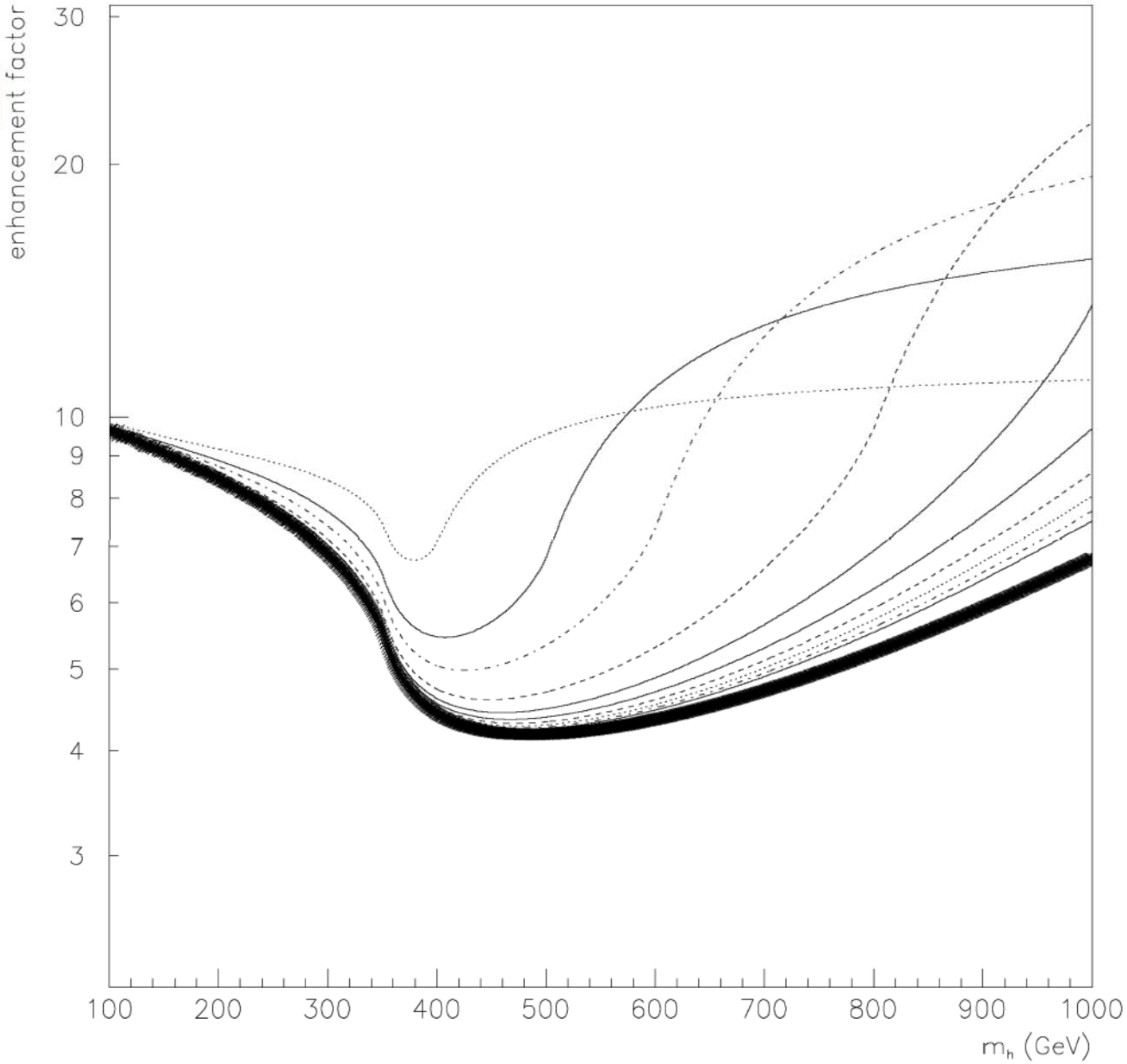
- enhancement factor as a function of the Higgs boson mass for infinitely heavy 4th family quark mass (pessimistic case)



Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

Enhancement of Higgs production cross section

- enhancement factor as a function of the Higgs boson mass for various finite 4th family quark masses compared to infinitely heavy 4th family quark mass (pessimistic case)



Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

Decays of the Higgs Boson

$$\Gamma(H \to \gamma\gamma) = \frac{G_F m_H^3}{8\sqrt{2}\pi}\left(\frac{\alpha}{\pi}\right)^2 |I|^2 \ ,$$

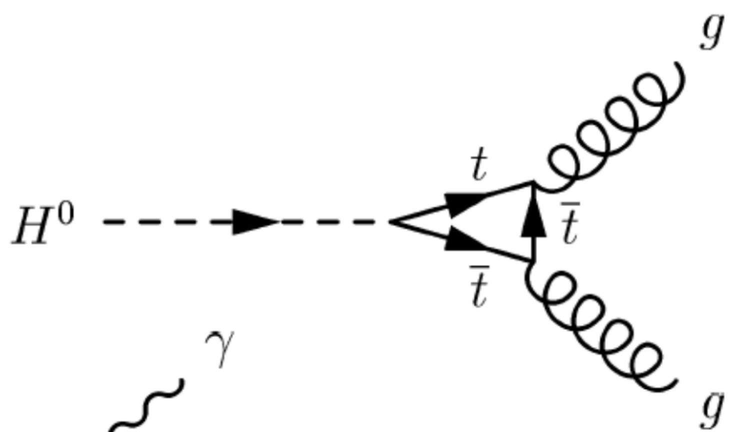
$$I = \Sigma_q Q_q^2 I_q + \Sigma_l Q_l^2 I_l + I_W + I_S \ ,$$

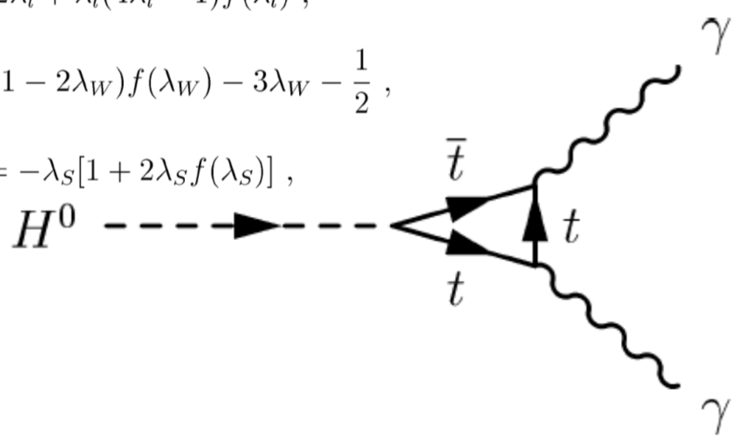
$$I_q = 3[2\lambda_q + \lambda_q(4\lambda_q - 1)f(\lambda_q)] \ ,$$

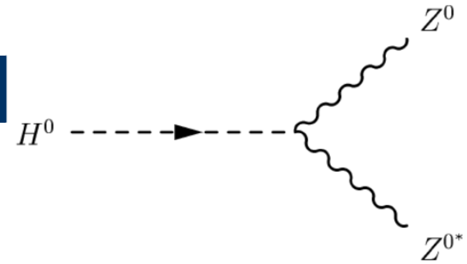
$$I_l = 2\lambda_l + \lambda_l(4\lambda_l - 1)f(\lambda_l) \ ,$$

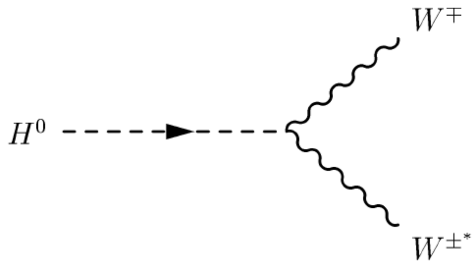
$$I_W = 3\lambda_W(1 - 2\lambda_W)f(\lambda_W) - 3\lambda_W - \frac{1}{2} \ ,$$

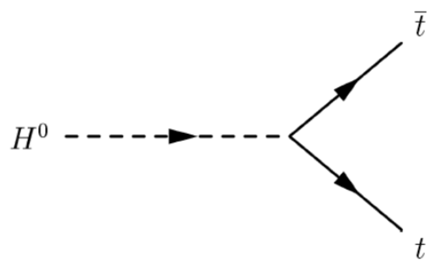
$$I_S = -\lambda_S[1 + 2\lambda_S f(\lambda_S)] \ ,$$

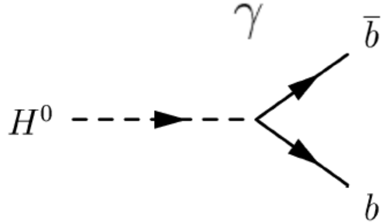


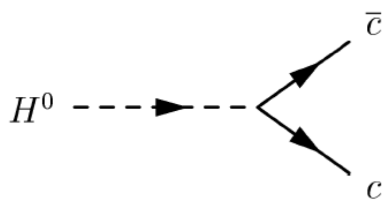


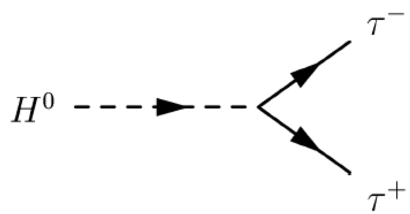








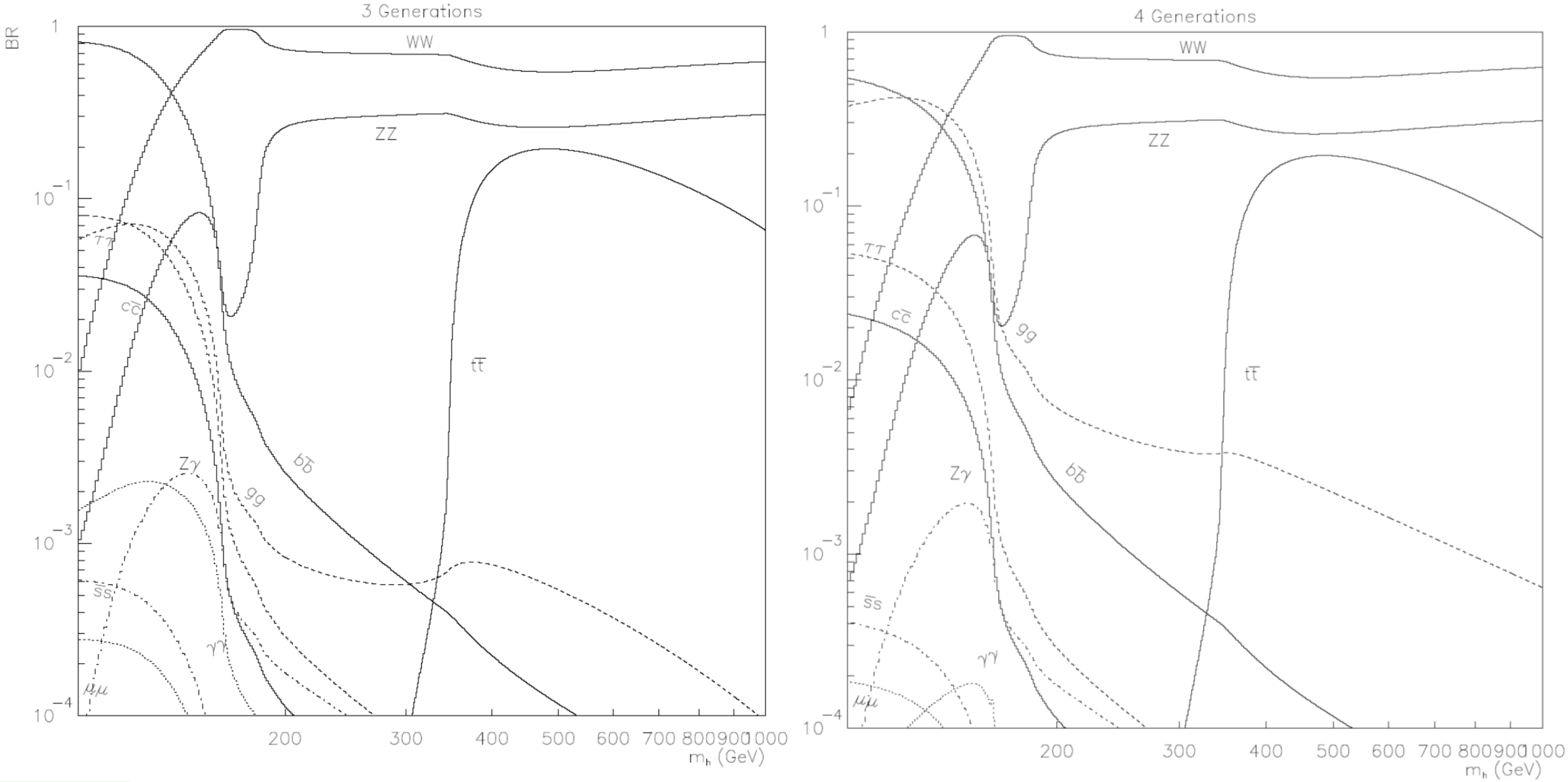




Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

Branching Ratios in 3 & 4* SM family cases

*** infinitely heavy degenerate masses**

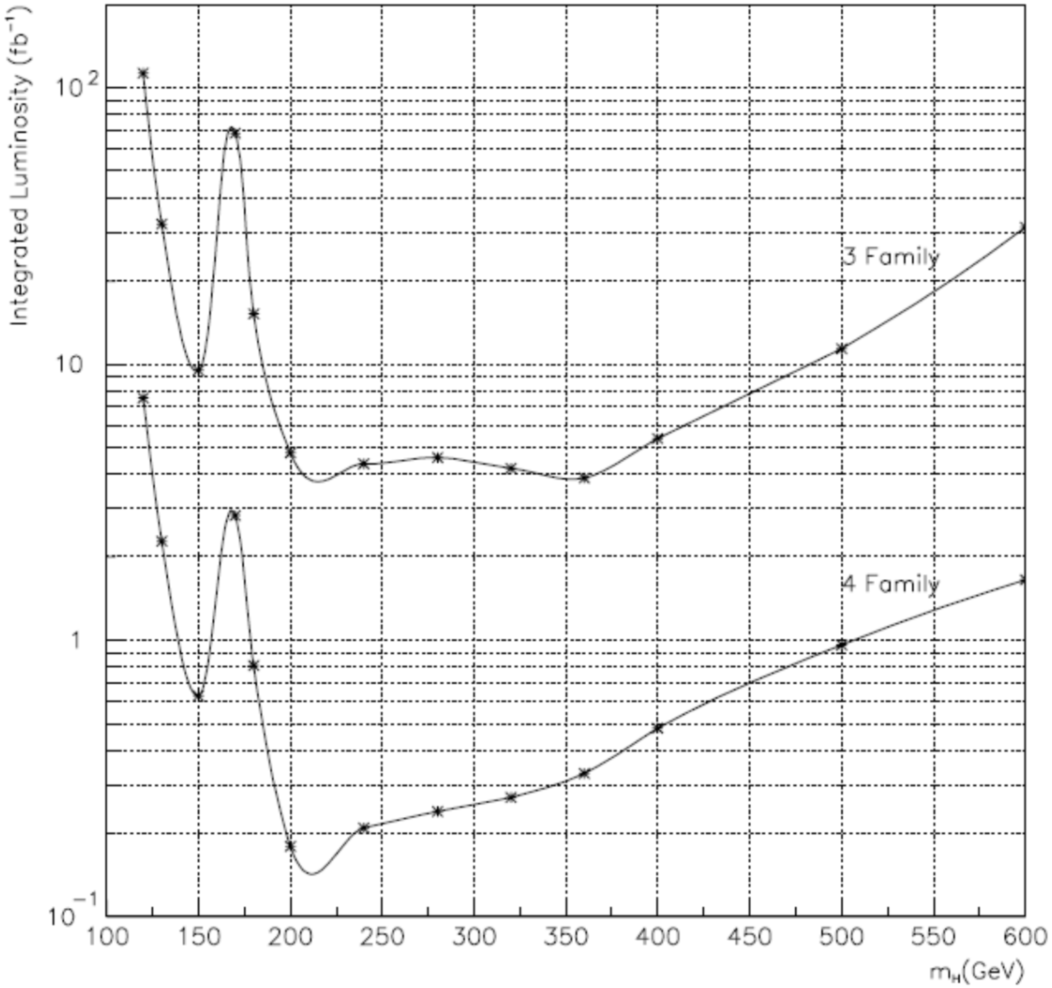


Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

Golden mode and a few fb^{-1} is just enough for ATLAS

SN-ATLAS-2001-006 / EPJ-C 26 (2002) 9-11

LHC luminosity values corresponding to 5σ significance level of the golden mode ($H \rightarrow ZZ \rightarrow 4l$) signal at ATLAS for 3* and 4 family cases



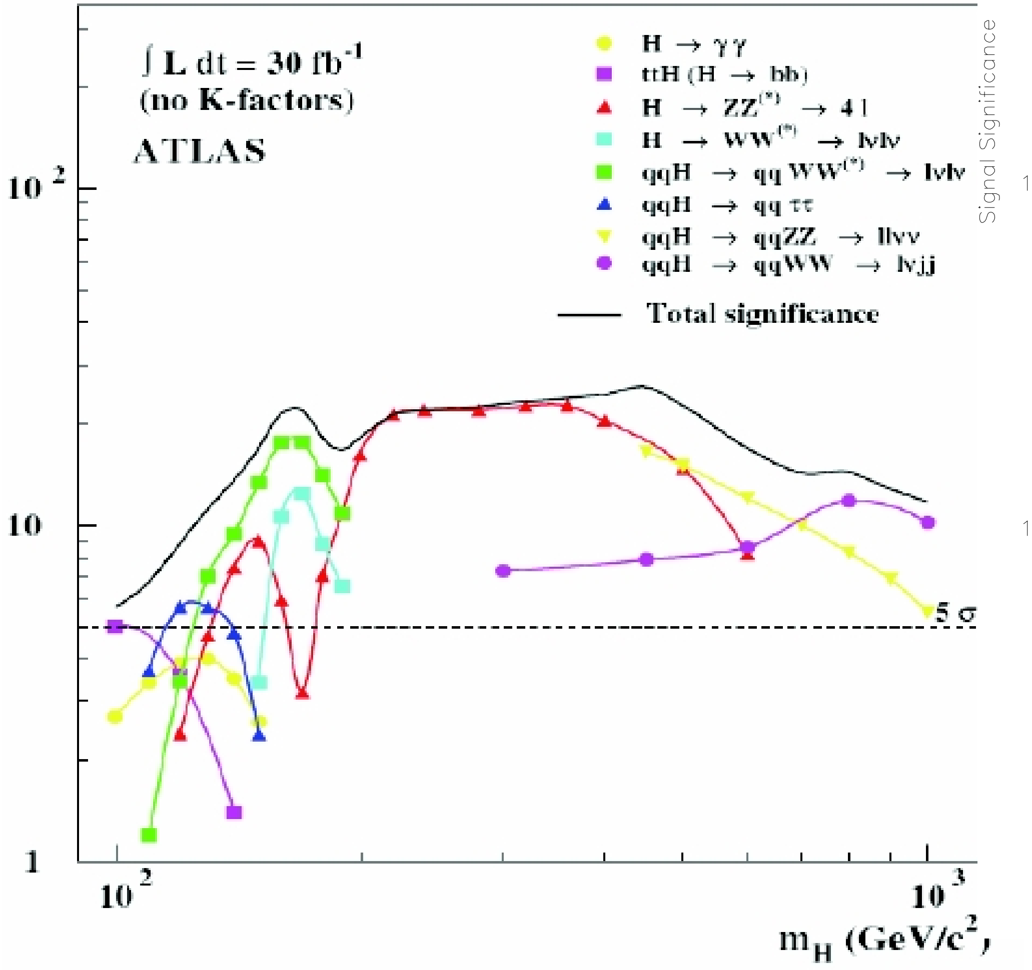
* from ATLAS TDR, CERN/LHCC/99-15, Vol. 2, Ch. 19

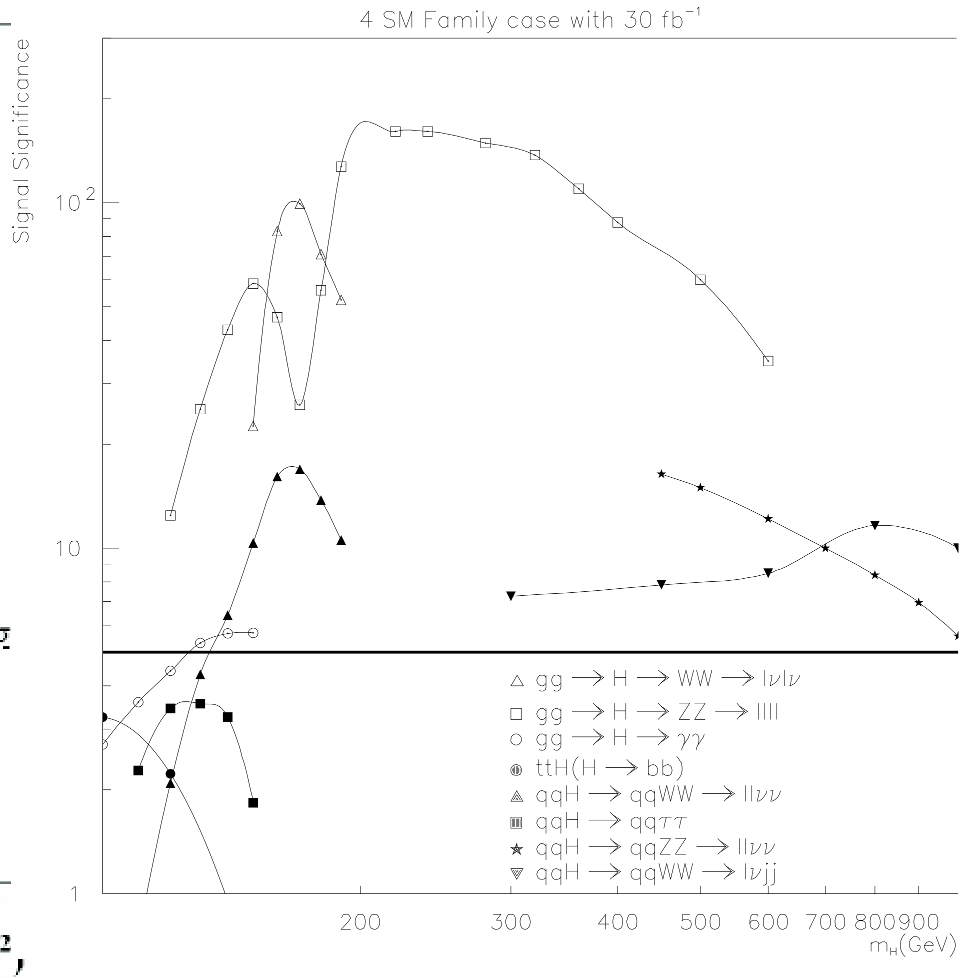
0708.0241

Balkan Physics Letters, 15(4) (2007)

Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

ATLAS sensitivity for the discovery of the SM Higgs boson ($30\ fb^{-1}$)



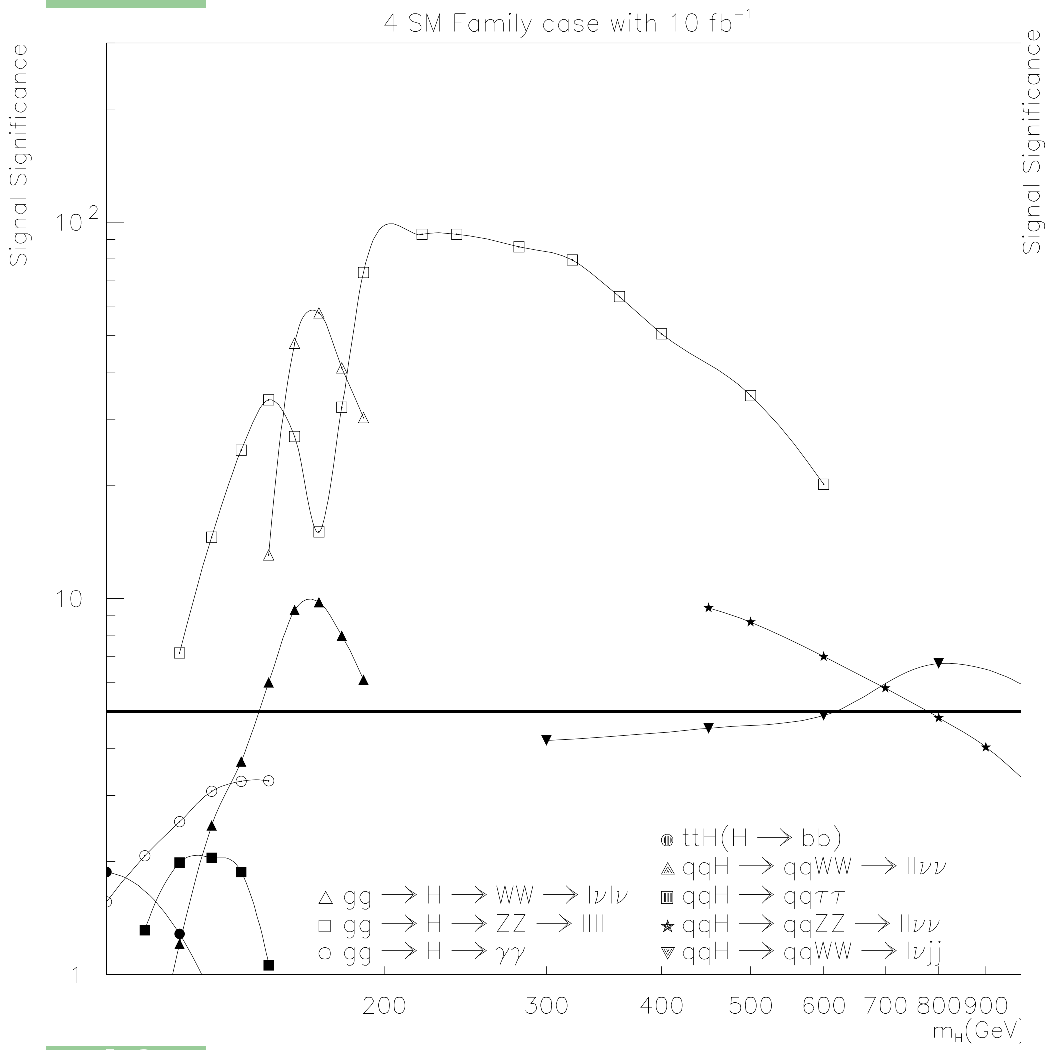


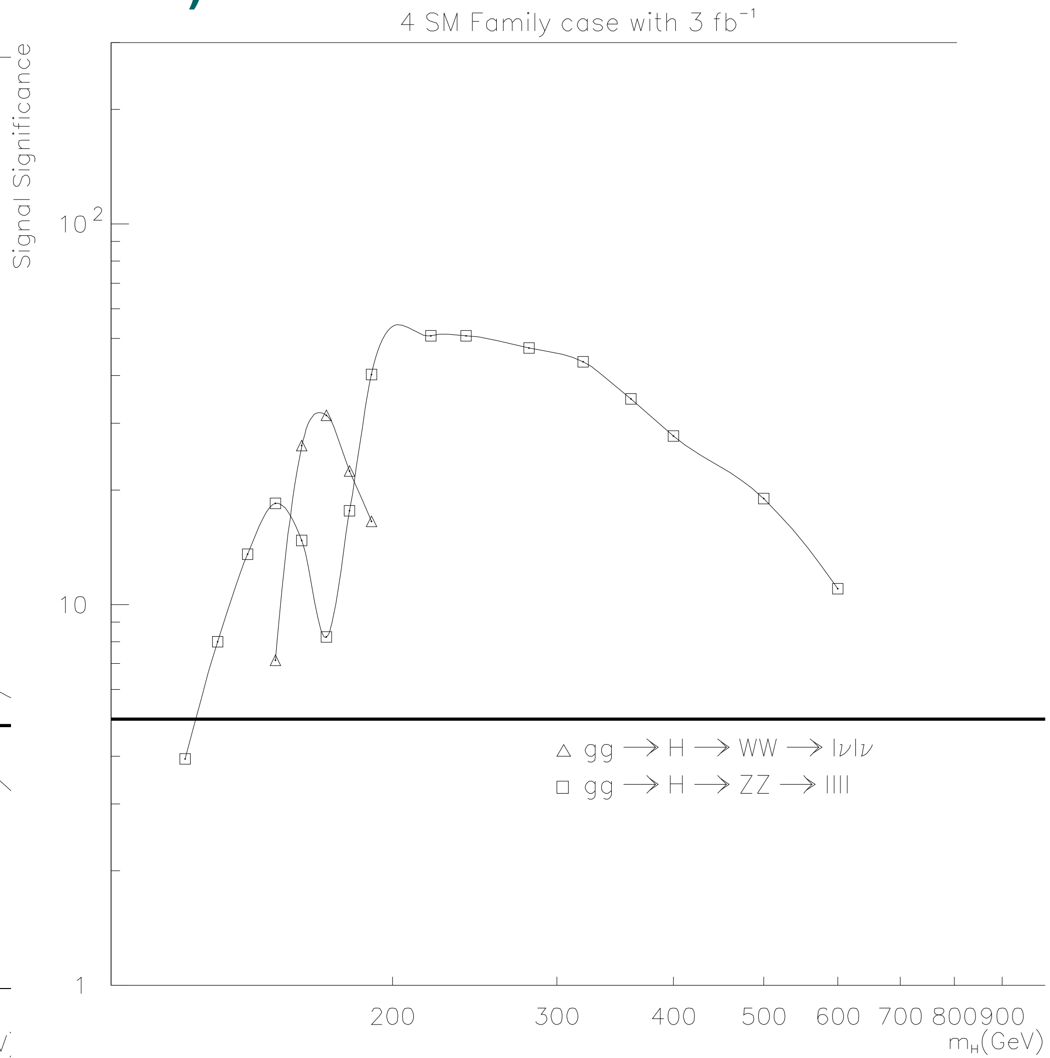
0708.0241

Balkan Physics Letters, 15(4) (2007)

Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

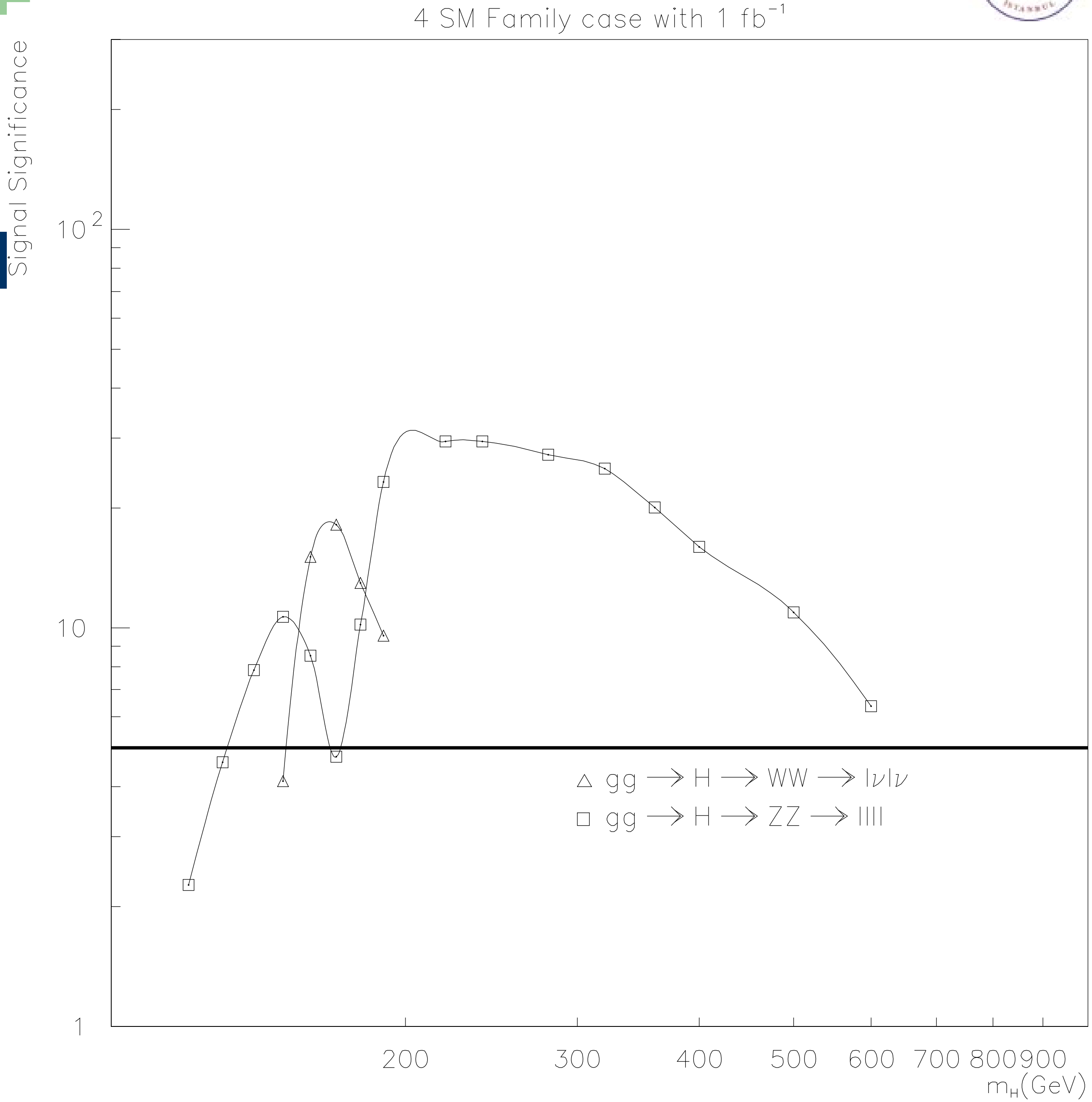
ATLAS sensitivity for the discovery of the SM Higgs boson (10 & 3 fb^{-1})





Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

- ATLAS sensitivity for the discovery of the SM Higgs boson in the 4 SM family case with an integrated luminosity of 1 fb^{-1}



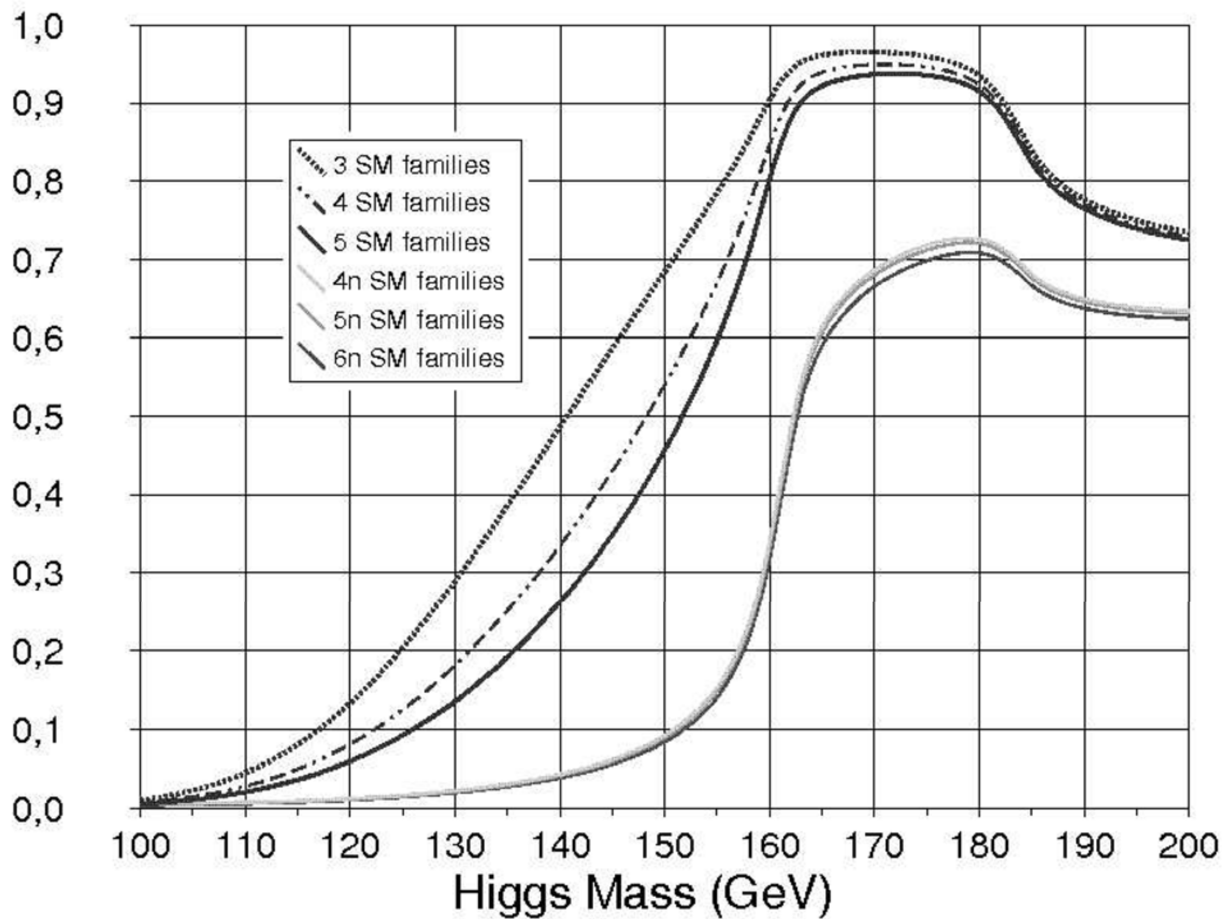
Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

4th family effects on Higgs at the Tevatron

(H→WW$^{(*)}$ upto 200GeV)

Acta Phys.Polon.B37:2839-2850,2006

Branching Ratio of H→WW in different scenarios.



Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

4th family effects on Higgs at the Tevatron

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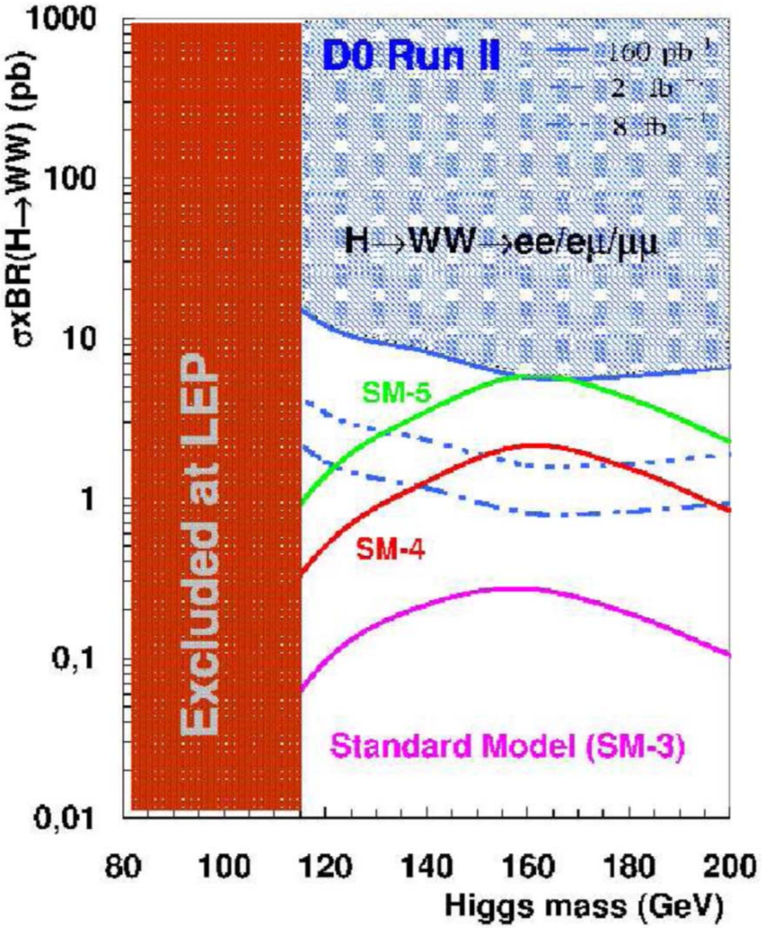
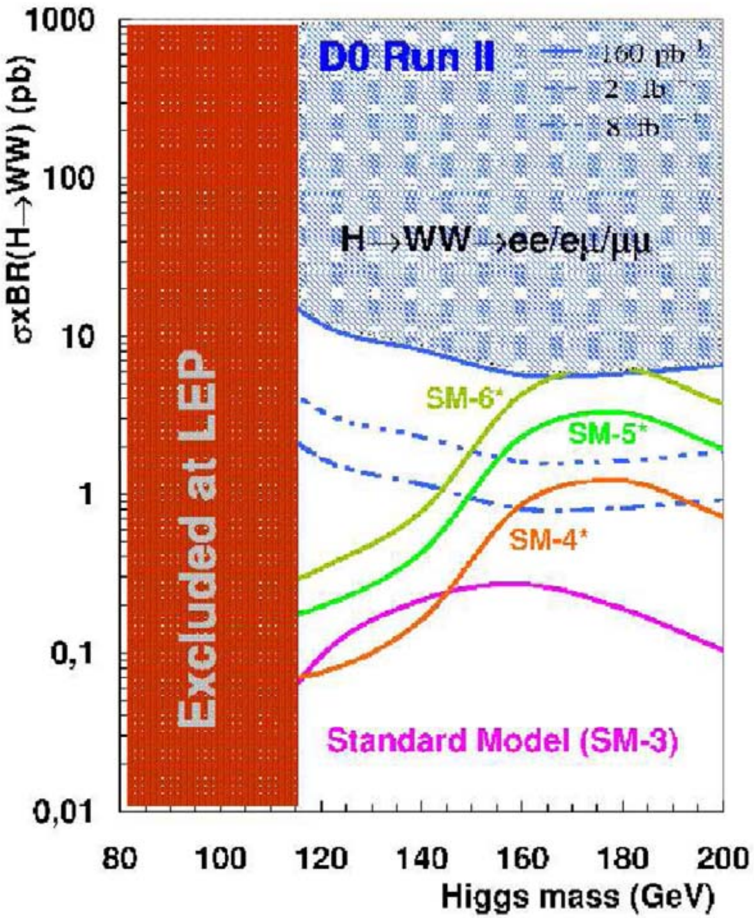




Phys.Rev.Lett. 97 (2006) 081802
Phys.Rev.Lett.96:011801,2006
A.Meyer / PIC06 - G. Bernardi / ICHEP06

4th family limits at the Tevatron

Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

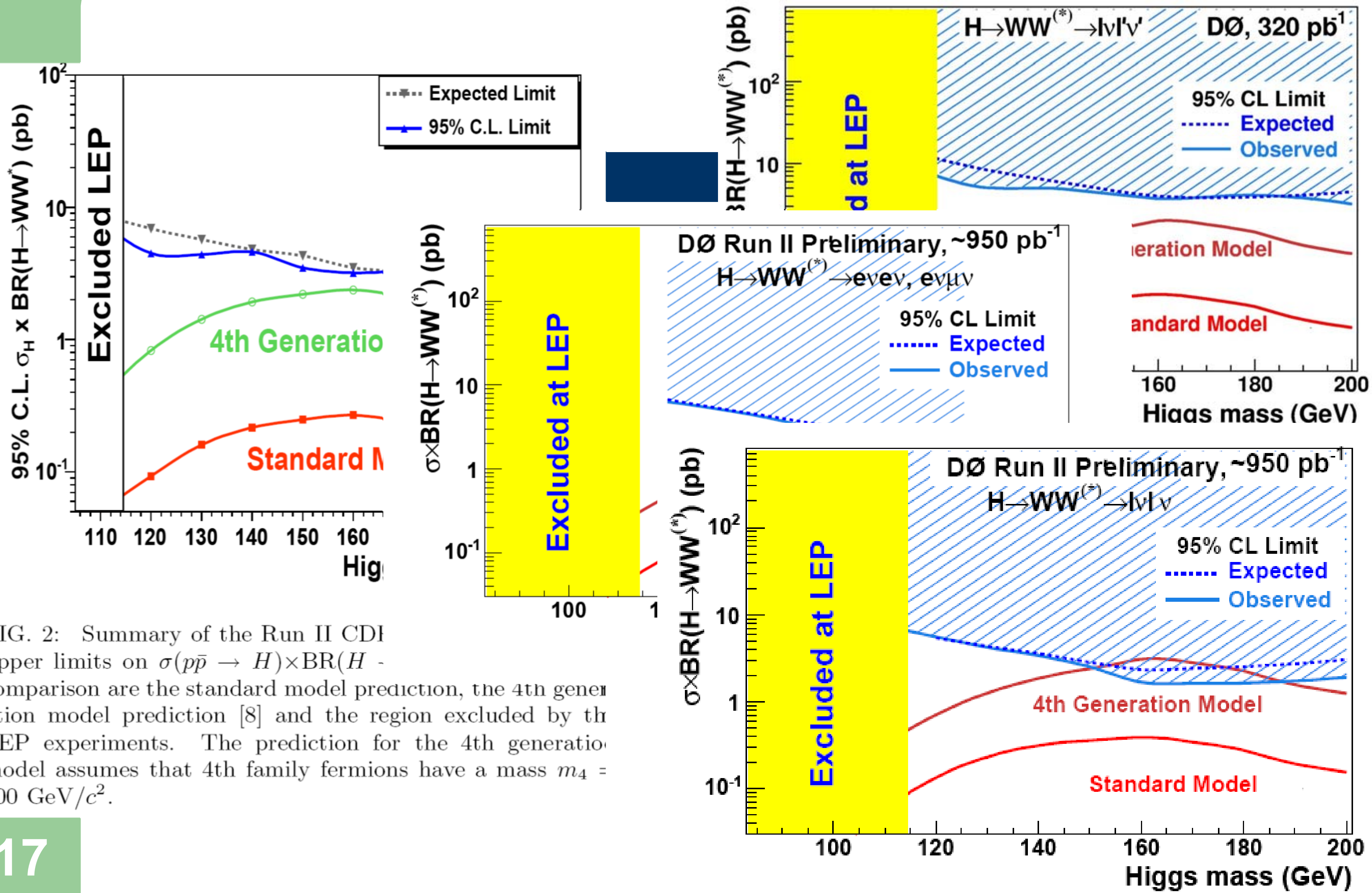
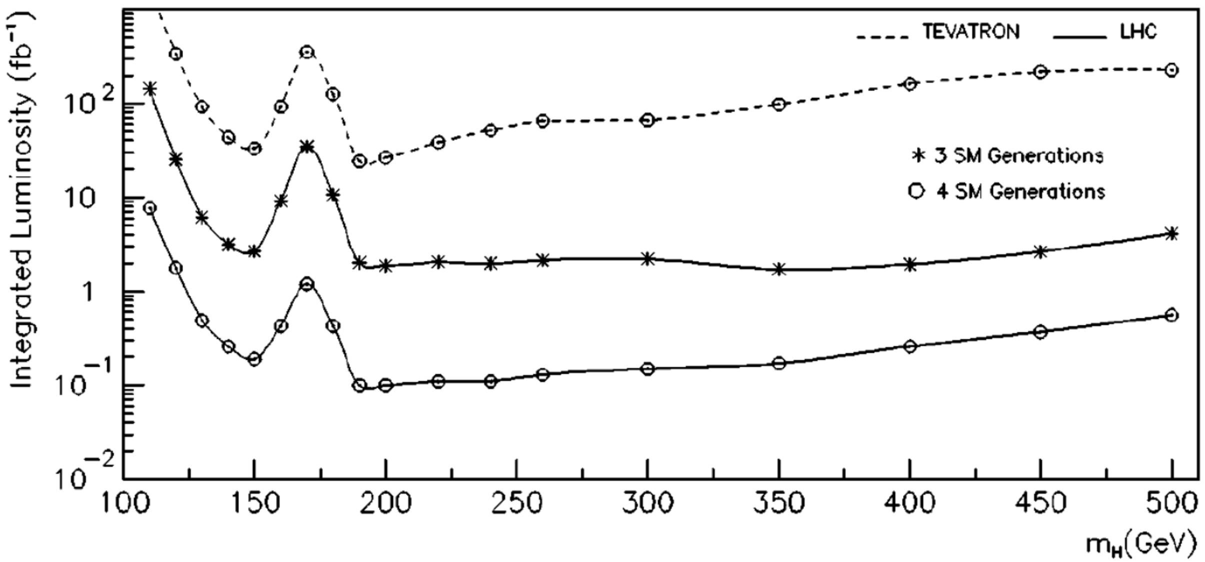


FIG. 2: Summary of the Run II CDI
upper limits on $\sigma(p\bar{p} \to H)\times BR(H$ -
comparison are the standard model prediction, the 4th gener
ation model prediction [8] and the region excluded by th
LEP experiments. The prediction for the 4th generatio
model assumes that 4th family fermions have a mass m_4 =
200 GeV/c^2.

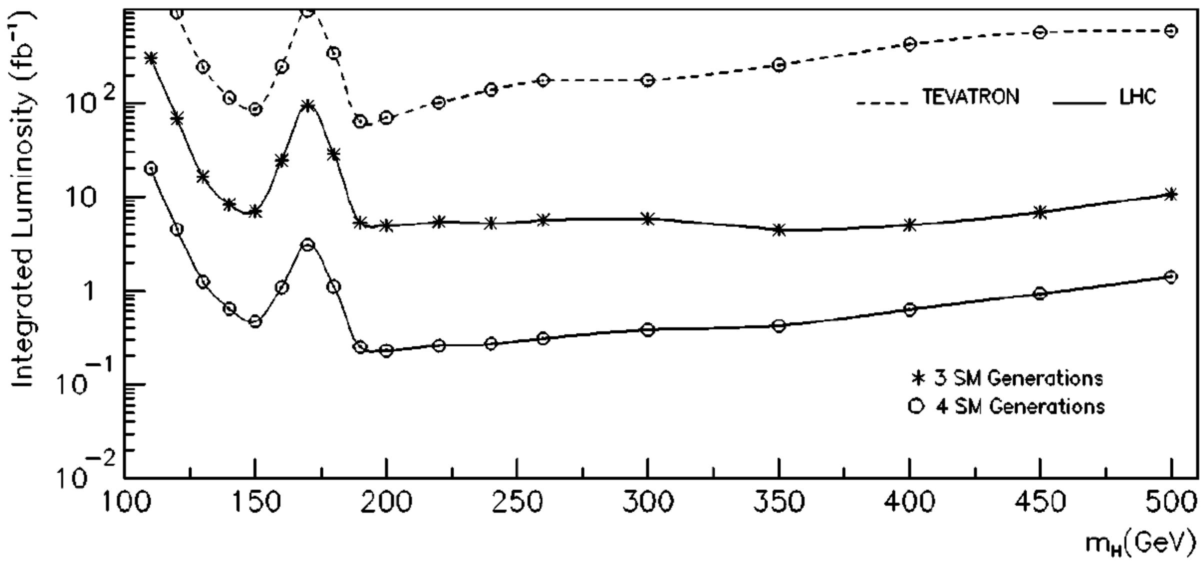
Phys.Rev.D66:033003,2002

Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

Comparing LHC with Tevatron in the golden mode



Luminosity needed to achieve 3σ significance for the golden mode



Luminosity needed to achieve 5σ significance for the golden mode

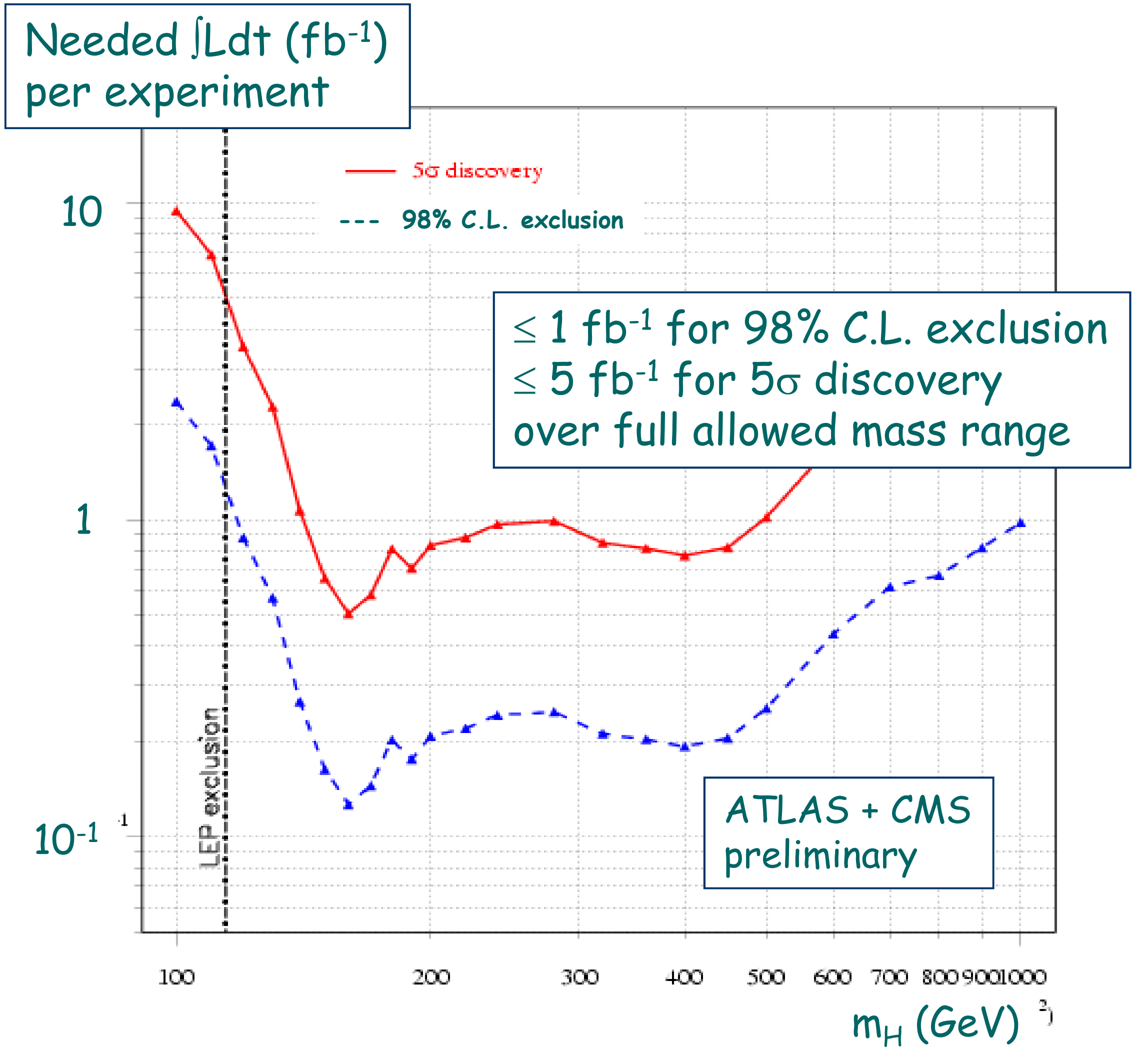
Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

Combined analysis efforts at the LHC

F.Gianotti/ICHEP06 – A.Ball/ICHEP08

LHC must be ready to address any early discovery:

ratio of the two lines compare with consequence of a fourth family



Serkant Ali Çetin
Dogus University / Istanbul
scetin@dogus.edu.tr

Conclusions

- Even with **a few fb^{-1}**, the golden mode covers almost all of the Higgs mass region at levels higher than **5 σ**. This can result in a **double discovery** or fourth family **exclusion** cases for corresponding higgs mass regions.
- Whichever happens, it happens much earlier than any higgs signal we might see in the SM-3 case, and will become the one of the **first discovery/exclusion result** of the LHC.
- It is also an opportunity for the Tevatron to have the possibility of accessing Higgs masses otherwise not accessible.
- LHC experiments must be ready to address any early Higgs discovery